The Seventeenth Book Of Natural Magick

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Now I am come to Mathematical Sciences, and this place requires that I show some experiments concerning Catoptrick glasses. For these shine among geometrical instruments, for ingenuity, wonder and profit. For what could be invented more ingeniously, then that certain experiments should follow the imaginary conceits of the mind, and the truth of mathematical demonstrations should be made good by ocular experiments? What could seem more wonderful, then that by reciprocal strokes of reflection, images should appear outwardly, hanging in the air, and yet neither the visible object nor the glass seen? That they may seem not to be the repercussion of the glasses, but spirits of vain phantasms? To see burning glasses, not to burn alone where the beams unite, but at a great distance to cast forth terrible fires, and flames, that are most profitable in warlike expeditions, as in many other things. We read that Archimedes at Syracuse with burning glasses defeated the forces of the Romans. And that King Ptolomey built a tower in Pharos, where he set a glass, that he could see for six hundred miles, see by it the enemy ships, that invaded his country and plundered it. I shall add also those spectacles, whereby poor blind people can at great distance, perfectly see all things. And though venerable antiquity seem to have invented many and great things, yet I shall set down greater, more noble, and more famous things, and that will not a little help to the optic science, that more sublime wits may increase it infinitely. Lastly, I shall show how to make Crystal and metal glasses, and how to polish them.

Chapter I

"Diverse representations made by plain Glasses."

shall begin with plain glasses, for they are more simple, and the speculations thereof, are not so laborious, though the apparitions of them be almost common, yet they will be useful for what follows. And we shall add some secret apparitions unto them. The variety of the images that appear, proceed either from the matter or form of the glass. Crystal must be clear, transparent, and exactly made plain on both sides. And if one or both of these be wanting, they will represent diverse and deformed apparitions to our sight. I shall therefore begin from the matter, and show,

"How apparitions may seem to him that looks upon them, to be pale, yellow, or of diverse colors."

When the glass is melted with heat in the furnace, with any little color it will be tainted. If you cast in yellow, the face of him that looks into it, will seem to have the Yellow Jaundices. If black, he will appear wan and deformed. If you add much of it, like to a Blackmoore. If red, like a drunkard or furious fellow. And so will it represent images of any color. How to mingle the colors, I taught when I spoke of jewels. I have often made sport with the most fair women, with these glasses. When they looked, and saw not themselves as they were, but there are many varieties arise from the form.

"That the face of him that looks on the Glass may seem to be divided in the middle,"

Let the superficies of the Looking-glass that you look on, be plain, and exactly polished by rule. But the backside must have a blunt angle in the middle, that the highest part of it may be in the middle. In the outward parts it must be sharp and pressed down; Then lay on the Foil. Wherefore the image that falls on your sight, where the lines meet in the angle, will seem divided in two. If you will,

"That he that looks in the Glass, shall seem like an Ass, Dog, or Sow."

By variation of the place, the angles, and the representation of the form beheld, will seem various. If that part of the glass, that is set against your mouth, shall stick forth before like a wreathed band or a Boss-buckler, you mouth will appear to come forth like an ass's or sows snout. But if it swell forth against your eyes, your eyes will seem to be put forth like shrimps eyes. If the angle be stretched forth by the length of the glass, your forehead, nose, and chin, will seem to be sharp, as the mouth of a Dog.

That the whole face may seem various and deformed."

Let a plain glass not be exactly plain and even. Which that it may be done, when the glass is once made plain, put it into the furnace again, and let it be turned by the skillful hand of an artist, till it lose its right position, then soil it. Then the image on the hollow part of the glass, will represent the opposite part hollow. So it will hold forth one lying along on his face, or crooked, and swelling outwardly and inwardly. Then if when the glass is polished, one side be rubbed, the face will seem long and broad. Wherefore it must be rubbed, and fashioned on all sides, that it may every way represent a perfect face. I shall show you also,

"How to make a Glass to represent many images."

That it may show diverse images one after another, and of diverse colors, make the solid body of the Looking-glass, or glass that is half a finger thick, and let it be so planed, that upon one side, the thickness may not be touched, but on the other side, the lines of the two superficies may meet, as the sharp edge of a knife. Make also another table of glass the same way. Or else more, lay a Foil of Tin upon the last, and place one of them upon the thick part of the other. So will the face of one that looks into it, appear to be two, one behind the other, and the nethermost will always appear darkest. So if by the same artifice, you fit three tables of glass, the image will appear to be three, and the farther he that looks, stands with his face from the glass, the farther will those images or faces stand asunder. But as you come very near, they seem to join all in one. If you hold a candle lighted against it, there will be many seen together, which comes by the mutual reciprocation of the sight and the glass. And if the polishers of glasses, putting one aptly above another, but let one be distant from the other by certain courses, then shut them in a frame, that the art may not be discovered. Nor will I omit,

"How letters may be cast out and read, on a wall that is far distant."

Which we shall do with the same plain glass. And lovers that are far asunder, may so hold commerce one with another. On the superficies of a plain glass, make letters with black ink, or with wax, that they may be solid to hinder the light of the glass, and shadow it. Then hold the glass against the sunbeams, so that the beams reflecting on the glass, may be cast upon the opposite wall of a chamber, it is no doubt but the light and letters will be seen in the chamber, the suns light will be clearest, and letters not so bright, so that they will be clearly discovered, as they are sent in.

Chapter II

"Other merry sports with plain Looking-glasses."

Now I shall annex some other operations of a plain glass, described by our ancestors, that I may seem to leave out nothing. And I will so augment them, and bring them to a rule, that they may be easily made. I shall begin with this,

"How by plain Looking-glasses, the head may appear to be downwards, and the heels upwards."

If any man by plain glasses, desires to see his head downward, and his feet upward (though it is proper for Concave glasses to

represent that) yet I will endeavour to do it by plain glasses. Place two glasses longways, that they may stick together and cannot easily come asunder, or move here and there, and that they make a right angle. When this is so done, according to coherence the long way, set this against your face, that in one, half the face, in the other the other half may be seen. Then incline the Looking-glass to the right or left hand, looking right into it, and your head will seem to be turned, for according to their latitude, they will cut the face into two, and the image will appear so, as if the head were under, and the heels upwards. And if the glass be large, the whole body will seem to be inverted. But this happens from the mutual and manifold reflection, for it flies from one to the other, that it seems to be turned. We may,

"Make a plain glass that shall represent the Image manifold."

A glass is made that will make many representations, that is, that many things may be seen at once. For by opening and shutting it, you shall see twenty fingers for one, and more. You shall make it thus; Raise two Brass Looking-glasses , or of Crystal, at right angles upon the same Brass, and let them be in a proportion called Sesquialtera, that is, one and half, or some other proportion, and let them be joined together longways, that they may be shut and opened like to a book. And the angles be diverse, such as are made at Venice. For one face being objected, you shall see many in them both, and this by so much the straighter, as you put them together, and the angles are less. But they will be diminished by opening them, and the angles being more obtuse, you shall see the fewer. So showing one figure, there will be more seen. And farther, the right parts will show right, and the left to be the left, which is contrary to Looking-glasses. And this is done by mutual reflection and pulsation, whence arises the variety of images interchangeably. We may,

"Make a Glass of Plain glasses, wherein one image coming, is seen going back in another."

Take two plain glasses, the length whereof shall be double, or one and half to the latitude, and that for greater convenience. For the proportion is not material, but let them be of the same length, and equal, and laid on the top of a pillar, inclining one to the other, and so joined together. And let them be set upright upon someplace perpendicularly, so the glasses fastened, may be moved on the movable side. It is no doubt but you shall see the image to come in one,and go back in the other glass. And the more this comes near, the farther will the other go. And in one will it be seen coming, and in the other going. Also you may see,

"In plain Glasses those things that are done afar off, and in other places."

So may a man secretly see, and without suspicion, what is done afar off, and in other places, which otherwise cannot be done. But you must be careful in setting your glasses. Let there be a place appointed in a house or elsewhere, where you may see anything, and set a glass right over against your window, or hose, that may be toward your face, and let it be set straight up if need were, or fastened to the wall, moving it here and there. Inclining it till it reflect right against the place. Which you shall attain by looking on it, and coming toward it. And if it be difficult, you cannot mistake, if you use a Quadrant or some such instrument. And let it be se perpendicular upon a line, that cuts the angle of reflection, and incidence of the lines, and you shall clearly see what is done in that place. So it will happen also in diverse places. Hence it is, that if one glass will not do it well, you may do the same by more glasses. Or if the visible object be lost by too great a distance, or taken away by walls or mountains coming between, moreover, you shall fit another glass just against the former, upon a right line, which may divide the right angle, or else it will not be done, and you shall see the place you desire. For one glass sending the image to the other tenfold, and the image being broken by many things, flies from the eye, and you shall see what you first light upon, until such time as the image is brought to you by right lines, and the visible object is not stopped by the winding of places or walls. And the placing of it is easy. So often I use to convey images of things. But if otherwise you desire to see any high place, or that stands upright, and your eye cannot discern it. Fit two Looking-glasses together longways, as I said, and fasten one upon the top of a post or wall, that it may stand above it, and the object may stand right against it. The other to a cord, that you may move it handsomely when you please, and that it may make with the first sometimes a blunt, sometimes a sharp angle, as need requires, until the line of the thing seen may be refracted by the middle of the second glass to your sight, and the angles of reflection and incidence be equal. And if you seek to see high things, raise it. If low things, pull it down, till it beat back upon your sight, and shall you behold it. If you hold one of them in your hand, and look upon that, it will be more easily done. I

show you also,

"How to make a Glass that shall show nothing but what you will."

Also a glass is so framed, that when you look into it, you shall not see your own picture, but some other face, that is not seen anywhere round about. Fasten a plain glass on a wall upon a plain, set upright perpendicularly, and bow the top of it to the known proportion of the angle. Right against it cut the wall, according as the proportion of some picture or image may require, and set it by it, according to a fit distance, and cover it, that the beholder may not see it (and the matter will be the more wonderful) nor can come at it. The glass at a set place will beat back the image, that there will be a mutual glance of the visible object and the sight, by the Looking-glasses. There place your eye, you shall find that place, as I taught you before. Wherefore the spectator going thither, shall neither see his own face, nor anything else besides. When he is opposed to it, and comes to the set place, he shall see the image or the picture, or some such thing, which he can behold nowhere else. You shall now how,

"How a Glass may be made of plain glasses, whereby you may see an image flying in the air."

Nor is that glass of less importance, or pleasure, that will represent men flying in the air. If any man would do it, it is easily done thus. Fit two pieces of wood together like a square or gnomon of a dial, and being well fastened, they may make an angle as of right angled triangle, or isosceles. Fasten then at each foot one great Looking-glass, equally distant, right one against the other, and equidistant from the angle. Let one of them lie flat, and let the spectator place himself about the middle of it, being somewhat raised above the ground, that he may the more easily see the form of the heel going and coming. For presently you shall perceive, if you set yourself in a right line, that cuts that angle, and it be equidistant to the horizon. So the representing glass will send that image to the other, which the spectator looks into, and it will shake and move the hands and feet, as birds do when they fly. So shall he see his own image flying in the other, that it will always move, so he depart not from the place of reflection, for that would spoil it.

Chapter III

"A Looking-glass called a Theatrical Glass."

Prudent antiquity found out a Looking-glass made of plain glasses, wherein if one object might be seen, it would represent more images of the same thing, as we may perceive by some writings, that go in Ptolomy's name. Lastly, I shall add to this what our age has invented, that is far more admirable and pleasant.

"To make an ancient fashioned Looking-glass, wherein more pictures will represented of the same thing."

The way is this. Make a half circle on a plain table, or place where you desire such a glass to be set up. And divide this equally with points according to the number of the images you would see. Make subtendent lines to them, and cut away the arches. Then erect plain Looking-glasses, that may be of the same Latitude, and of the same parallel lines, and the same longitude. Glue them fast together, and fit them so, that they may not be pulled asunder, as they are joined lengthways, and erected upon a plain supersidies. Lastly, let the spectator place his eye in the center of the circle, that he may have his sight uniform, in respect of them all. In each of them you shall see several faces, and so quite round, as we see it often when people dance round, or in a theater, and therefore it is called a Theatrical Glass. For from the center all the perpendicular lines fall upon the supersicies, and they are reflected into themselves, so they reflect the images upon the eye, each of them drawn forth its own. This is the ancients way of making a Theatrical Glass, but it is childish. I will show you one that is far more pleasant,

and wonderful. For in the former, the images were seen no more then the glasses were in number. But in our glass, by the manifold and reciprocal dartings of the object and the glass, you may see far more, and almost infinite images. The way is this,

"How to make an Amphitheatrical Glass."

Make a circle on a table what largeness you desire, and divide it into equal parts. And in the place where the object or face to be seen must be opposed, leave two void spaces. Over against the parts, let a right line be made upon the lines that determine the parts. Let Looking-glasses be raised perpendicularly, for the face that shall be against the Looking-glass, placed in the middle, will fly back to the beholder of it, and so rebounding to another, and from them to another. By many reflections you shall see almost infinite faces, and the more glasses there are, the more will be the faces. If you set a candle against it, you shall see innumerable candles. But if the glasses you erect, shall be of those already described, from so many diverse faces of asses, sows, horses, dogs. And of course colors, yellow, brown, red, the spectators shall see a far more wonderful and pleasant sight, for by reason of the manifold reflection, and diversity of the forms of the glasses, and colors, an excellent mixture will arise.

But I will now make one that is far more wonderful and beautiful. For in that the beholder shall not see his own face, but a most wonderful, and pleasant, an orderly form of pillars, and the basis of them, and variety of architecture. Make therefore a circle as you would have it for magnitude, but I hold the best to be where the diameter is two foot and a half. Divide the circumference into equal parts, as for example, into fourteen. The points of the divisions shall be the places, where the pillars must be erected. Let the place where the spectator must look, contain two parts. And take one pillar away, so there will be thirteen pillars. Let one pillar be right against the sight. Then raise Looking-glasses upon the lines of space between, not exactly, but inclined. Place then two Looking-glasses at opposition to a right line, but the rest about the beginning, where they join, and that for not other reason, but that the beholders face, being not rightly placed, may not be reflected, as I said before. For thus the glasses will not represent faces, but pillars, and spaces between, and all ornaments. Hence, by the reciprocal reflection of the glasses, you shall see so many pillars, bases, and varieties, keeping the right order of architecture, that nothing can be more pleasant, or more wonderful to behold. Let the perspective be the Dorick and Corinthian, adorned with gold, silver, pearls, jewels, images, pictures, and such like, that it may seem the more magnificent. The form of it shall be thus. Let H. G. be the place for the beholder to look. The pillar against him shall be A, in the glass A B, or A C, the face of the beholder shall not be seen, but A B is reflected into I H, and I H into B D, so by mutual reflections they are so multiplied, that they seem to go very far inwardly, so clearly and apparently, that no spectator that looks into it, unless he know it, but he will thrust his hands in to touch the others. If you set a candle in the middle, it will seem so to multiply by the images rebounding, that you shall not see so many stars in the sky, that you can never wonder enough at the order, symmetry, and prospect. I have raised and made this amphitheater diverse ways, and to show other orders, namely two ranks of pillars, so that the one stuck to the glasses, the other stood alone in the middle, bound with the chief arches, and with divers ornaments, that it may seem to be a most beautiful perspective or architecture. Almost the same way is there made a little chest of many plain glasses, covered round. This they call the Treasury. On the ground, arches and walls, were there pearls, jewels, birds, and monies hanging, and these were so multiplied by the reflections of the glasses, that it represented a most rich treasury indeed. Make therefore a chest of wood, let the bottom be two foot long, and one and half broad. Let it be open in the middle, that you may well thrust in your head. On the right and left hand, erect the sideboards a foot long, semicircular above, that it may be arched, but not exactly circular. Namely, divided into five parts each a hand-breadth. Cover this all about with glasses. Where the glasses join, there put pearls, precious stones, specious flowers, diverse colored birds. Above the bottom set heaps of gold and silver medals. From the arches, let there hang pearls, fleeces of gold. For when the coffer is moved gently, they will move also, and the images will moe in the glasses that it will be a pleasant sight.

Chapter IV

"Diverse operations of Concave-glasses."

But the operations of Concave-glasses are far more curious and admirable, and will afford us more commodities. But you can do nothing perfectly with it, until you know first the point of inversion. Therefore that you may do it the better and more easily,

"Know the point of Inversion of Images in a Concave-glass."

Do thus. Hold your glass against the sun, and where you see the beams unite, know that to be the point of inversion. If you cannot well perceive that, breathe a thick vapour from your mouth on it, and you shall apparently see where the coincidence is of the reflected beams. Or set under a vessel of boiling water. When you have found the point of inversion, if you will,

"That all things shall seem greater."

Set your head below that point, and you shall behold a huge face like a monstrous Bacchus, and your finger as great as your arm. So women pull hairs off their eyebrows, for they will show as great as fingers. Seneca reports that Hostius made such Concave-glasses , that they might make things show greater. He was a great provoker to lust. So ordering his glasses, that when he was abused by Sodomy, he might see all the motions of the Sodomite behind him, and delight himself with a false representation of his privy parts that showed so great.

"To kindle fire with a Concave-glass."

This glass is excellent above others, for this, that it unites the beams so strongly, that it will show forth a light pyramis of its beams, as you hold it to the sun. And if you put any combustible matter in the center of it, it will presently kindle and flame, that with a little stay will melt lead or tin, and will make gold or iron red hot. And I have heard by some, that gold and silver have been melted by it. More slowly in winter, but sooner in summer, because the medium is hotter. At noon rather than in the morning, or evening for the same reason.

"To make an image seem to hang in the air, by a Concave-glass."

This will be more wonderful with the segment of a circle, for it will appear farther from the glass. If you be without the point of inversion, you shall see your head downwards. That with fixed eyes, and not winking at all, you may behold the point, until it comes to your very sight. For where the Cathetus shall cut the line of reflection, there the species reflected will seem almost parted from the glass. The nearer you are to the center, the greater will it be, that you will think to touch it with your hands. And if it be a great glass, you cannot but wonder, for if any man run at the glass with a drawn sword, another man will seem to meet him, and to run through his hand. If you show a candle, you will think a candle is Pendulons lighted in the air. But if you will

"That the image of a Concave-glass should go out far from the center."

When you have obtained the image of the thing in its point, if you will have it farther distant from the center, and that the picture of a thing shall be farther stretched forth, then you shall decline from the point a little toward the right or left hand, about the supersicies of the glass, and the image will come forth the farther, and will come to your sight. There, namely where the Cathetus does the farthest off that is possible touch the line of reflection, which few have observed. From which principle many strange wonders may be done. When you have this, you may easily,

"Reflect heat, cold, and the voice also, by a Concave-glass."

If a man puts a candle in a place, where the visible object is to be set, the candle will come to your very eyes, and will offend them with its heat and light. But this is more wonderful, that as heat, so cold, should be reflected. If you put snow in that

place, if it come to the eye, because it is sensible, it will presently feel the cold. But there is a greater wonder yet in it. For it will not only reverberate heat and cold, but the voice also, and make an echo. For the voice is more rightly reflected by a polite and smooth superficies of the glass, and more completely than by any wall. I prove this, because, if a man turns his face to the glass, and his friend stands far behind his back, when he beholds his face, he shall decline his face from the point of inversion. But on the right hand, about the supersicies of the glass, his face will come far from the glass, and will seem very great about the face of his friend. Whatsoever he shall speak with a low voice against the glass, he shall hear the same words and motions of his mouth, and all motion from the mouth of the reflected image. And they that stand in the middle between them, shall perceive nothing at all. But he that would send his won image to his friend, must observe till his head shall come to the glass. It is profitable also,

"By a Concave-glass to see in the night what is done afar off."

By this very glass, we may in a tempestuous night, in the middle of the streets, cast the light a great way, even into other men's chambers. Take the glass in your hand, and set a candle to the point of inversion, for the parallel beams will be reflected to the place desired, and the place will be enlightened above sixty paces, and whatsoever falls between the parallels, will be clearly seen. The reason is, because the beams from the center to the circumference, are reflected parallel, when the parallels come to a point. And in the place thus illuminated, letters may be read, and things done conveniently, that require great light. By the same art we may,

"With a few small lights give light to a great hall."

In temples, watches, and nightly feasts, any man may thus with a few lights make a great light. At two or more places of the chamber set Concave-glass above, and let them be so ordered. That the place of concurrent parallels may be coincident in the place required. And in the point of inversion of them, the light will be so multiplied, that it will be as light a noon-day. Lamps are best for this purpose, because the light varies not from the place. Candles are naught, because they alter the places of reflection. More commodiously then by a plain glass, to signify by a Concave-glass secretly some notes to your friend. Thus, do as I said, make the marks upon your glass superficies with wax or some dark substance, and setting it against the light, it will cast the light upon the walls of the chamber, and there it will be dark where the letters are made. One that knows the craft, may easily read them. But this is more admirable for one that knows not the cause,

"To read letters in a dark night."

A Concave-glass is of great use for this, and it may be this may be good in time of necessity. Set your Concave-glass against the starts of the first magnitude, or against Venus or Mercury, or against a fire or light that is far off. For the light reflected will meet in the point of burning, and reflects a most bright light, whereby you may easily read the smallest of letters, for putting the point of reflection to every word, you shall see all clearly. But this is more necessary and profitable,

"At any hour of the day with a Concave-glass, to set a house or fort on fire."

You may so burn the enemy ships, gates, bridges, and the like, without danger or suspicion, at a set hour of the day, appointed the day before. Set your glass against the sun, and order it so, that the coincidence of the beams may fall upon the point. Lay fuel there, and things that will take fire, as I have shown you. And if you would blow up towers, make heaps of Gunpowder. At night, set your glass, and hide it, that it may not be seen, for the next day the sun will fall upon the same point, where you set fuel for the fire.

Chapter V

"Of the mixed operations of the plain Concave-glasses."

I shall set down the mixed operations and benefits of both these glasses, that what one cannot do alone, it may do by the help of another. If we would,

"Kindle fire afar off with a plain and a Concave-glass ."

It falls out sometimes that one shut up in prison needs fire, and sun beams do not shine in. Or else I will show how we may kindle Gunpowder without fire, or make mines and fill them with Gunpowder, to blow up castles or rocks far off without danger, setting them on fire by a plain glass. A plain glass as it receives the parallel beams of the sun, it so reflects them, and therefore will cast the beams that are equidistant, a great way. But if a Concave-glass receive them, it so unites them, that it sets things on fire. Wherefore, first proving where the Concave-glass must be placed, that it may fire the fuel cast in. the next day, at the hour appointed, let the glass, cast in the beams upon the Concave-glass , that will unite them. So without danger, or any suspicion of the enemy, we may kindle fire for out use. Nor is it useless,

"That by a plain and Concave-glass , the smallest letters shall appear very great."

When letters are so small that they can only be seen. For I have seen St. John's Gospel, "In the beginning,..." written so small, in so little place, that it was no bigger than a small pimple, or the sight of a Cock's eye. By this artifice we may make them seem greater, and read them with ease. But a Concave-glass, with the back of it to your breast, over against it in the point of burning, set the writing. Behind set a plain glass, that you may see it. Then in the plain glass will the images of the characters be reflected, that are in the Concave-glass, which the Concave-glass has made greater, that you may read them without difficulty. You may,

"With a plain and Concave-glass , make an image be seen hanging altogether in the Air."

Do thus. I said that by help of a Concave-glass, an image may be sent forth. And this is seen by none but those that stand over against it. Set the Concave-glass to by your breast, without the center place a Poniard against it, and going farther off, set a plain glass against it. And looking in that, you shall see the image reflected from the Concave-glass, hanging in the air, and that exactly. But if an ingenious man observes it, he may wonderfully see an image hanging in the air, that is received in a plain glass, and sent far out as I have shown, without the help of a Concave-glass, and a visible spectacle, by the means of a plain glass only. You may also,

"By a plain Glass, see your face turned the wrong way."

When you have set the glass to your breast, as I said. Set a plain glass against it, and look upon it, it will cast it upon the Concave-glass, and that will beat it backwards on the plain glass. So have you your purpose.

Chapter VI

"Other operations of a Concave-glass ."

Before I part from the operations of this glass, I will tell you some use of it, that is very pleasant and admirable, whence great

secrets of nature may appear unto us. As,

"To see all things in the dark, that are outwardly done in the Sun, with the colors of them."

You must shut all the chamber windows, and it will do well to shut up all holes besides, lest any light breaking in should spoil all. Only make one hole, that shall be a hand breadth and length. Above this fit a little leaden or brass table, and glue it, so thick as a paper. Open a round hole i the middle of it, as great as your little finger. Over against this, let there be white walls of paper, or white clothes, so shall you see all that is done without in the sun, and those that walk in the streets, like to Antipodes, and what is right will be the left, and all things changed. And the farther they are off from the hole, the greater they will appear. If you bring your paper, or white table nearer, they will show less and clearer, but you must stay a while for the images will not be seen presently. Because a strong similarity does sometimes make a great sensation with the sense, and brings in such an affection, that not only when the senses do act, are they in the organs, and do trouble them, but when they have done acting, they will stay long in them. Which may easily be perceived. For when men walk in the sun, if they come into the dark, that affection continues, that we can see nothing, or very scantily, because the affection made by the light is still in our eyes. And when that is gone by degrees, we see clearly in dark places. Now will I declare what I ever concealed till now, and thought to conceal continually. If you put a small centicular Crystal glass to the hole, you shall presently see all things clearer, the countenances of men walking, the colors, garments, and all things as if you stood hard by. You shall see them with so much pleasure, that those that see it can never enough admire it. But if you will,

"See all things greater and clearer."

Over against it set the glass, not that which dissipates by dispersing, but which congregates by uniting, both by coming to it, and going from it, till you know the true quantity of the image, by a due appropinquation of the center. And so shall the beholder see more fitly birds flying, the cloudy sky, or clear and blue, mountains that are far off. And in a small circle of paper (that is put over the hole) you shall see as it were the epitomy of the whole world, and you will much rejoice to see it. All things backwards, because they are near to the center of the glass, if you set them farther from the center, they will show greater and upright, as they are, but not so clear. Hence you may,

"If you cannot draw a picture of a man or anything else, draw it by this means;"

If you can but only make the colors. This is an art worth learning. Let the sun beat upon the window, and there about the hole, let there be pictures of men, that it may light upon them, but not upon the hole. Put a white paper against the hole, and you shall so long sit the men by the light, bringing them near, or setting them further, until the sun casts a perfect representation upon the table against it. One that is skilled in painting, must lay on color where they are in the table, and shall describe the manner of the countenance, so the image being removed, the picture will remain on the table, and in the supersicies it will be seen as an image in the glass. If you will,

"That all shall appear right."

This is a great secret. Many have tried it, but none could obtain it. For some setting plain glasses obliquely against the hole, by reverberation against the table, they could see some things somewhat direct, but dark and discernible. I often by putting a white paper obliquely against the hole, and looking just against the hole, could see some things direct. But a Pyramis cut obliquely, did show men without proportion, and very darkly. But thus you may obtain your desire. Put against the hole a Convex-glass. From thence let the image reflect on a Concave-glass. Let the Concave-glass be distant from the center. So upon the hole and white paper, it will cast the images of the objects so clearly and plainly, that you will not wonder a little. But this I thought fit to let you understand, lest you fail in the work, that the Convex and Concave-glasses be proportionable circles. How you shall do this, will be here declared often. I shall show also,

"How in a Chamber you may see hunting, battles of enemies, and other delusions"

Now for a conclusion I will add that, then which nothing can be more pleasant for great men, and scholars, and ingenious persons to behold. That in a dark chamber by white sheets objected, one may see as clearly and perspicuously, as if they were before his eyes, huntings, banquets, armies of enemies, plays, and all things else that one desires. Let there be over against that chamber, where you desire to represent things, some spacious plain, where the sun can freely shine. Upon that you shall set trees in order, also woods, mountains, rivers, and animals that are really so, or made by art, of wood, or some other matter. You must frame little children in them, as we use to bring them in when comedies are acted. And you must counterfeit Stags, Boar, Rhinocerets, Elephants, Lions, and what other creatures you please. Then by degrees they must appear, as coming out of their dens, upon the plain. The hunter must come with his hunting pole, nets, arrows, and other necessaries, that may represent hunting. Let there be horns, Cornets, and trumpets sounded. Those that are in the chamber shall see trees, animals, hunters faces, and all the rest so plainly, that they cannot tell wether they be true or delusions.

"How you may see the sun eclipsed."

Now I have determined to show how the sun's Eclipse may be seen. When the sun is eclipsed, shut our chamber windows, and put a paper before a hole, and you shall see the sun. Let it fall upon the paper opposite from a Concave-glass, and make a circle of the same magnitude. Do so at the beginning, middle, and end of it. Thus may you without any hurt to your eyes, observe the points of the diameter of the sun's Eclipse.

Chapter VII

"How you may see in the dark what is light without by reason of torches."

We may demonstrate the same without the light of the sun, not without wonder. Torches, or lights lighted on purpose in chambers, we may see in another dark chamber what is done, by fitting things as I said. But the light must not strike upon the hole, for it will hinder operation. For it is a second light that carries the images. I will not conceal at last a thing that is full of wonder and mirth, because I fallen upon this discourse,

"That by night an image may seem to hang in a chamber."

In a tempestuous night the image of anything may be represented hanging in the middle of the chamber, that will terrify the beholders. Fit the image before the hole, that you desire to make to seem hanging in the air in another chamber that is dark. Let there be many torches lighted round about. In the middle of the dark chamber, place a white sheet, or some solid thing, that may receive the image sent in. For the spectators that see not the sheet, will see the image hanging in the middle of the air, very clear, not without fear and terror, especially if the artificer be ingenious.

Chapter VIII

"How without a Glass or representation of any other thing, an image may seem to hang in the air."

Before I part from this image hanging in the air, I will show how you may make the images of all things seem to hang in the air. Which will be the wonder of wonders. Chiefly being done without the apparition of a glass, or a visible object. But first we

will examine what the ancients write of this matter. One Vitellio describes the business after this fashion, thus: Fasten the segment of a cylinder to the middle of the house, set upon a table, or stool, that it may glance perpendicularly upon the ground. Then place your eye at some hole or chink that is somewhat distant from the glass, and let it be fixed, that it may not move here and there. Over against the glass break the wall, and make it like to a window. Let it be pyramidal in shape, and let the sharp point be within, and the basis without, as men use to do, when a picture or any image is placed for the eye to look upon. But let it be reflected on by the supersicies of the Pyramidal Glass, that the picture placed without, which your eye cannot see through the hole, may seem to hang pendoulous in the air, which will cause admiration to behold. Pyramidal Convex Glass will do the same, if you fit it so that it may represent the same image. It may be done also by a sphaerical Convex and Concave. But the matter promises more in the front piece written upon it, then it will perform in the conclusion. Wherefore the image will be seen without the glass, but by the means of the glass, so that the thing beheld in the glass, will seem to be without it. But he is foully mistaken here, as in other places. He had said better, by a cylinder of Crystal. For as a pillar it would make an irradiation outwardly, yet it would be worse seen than in the pillar, as I shall show. But I shall discover what I purposed always to conceal,

"That neither the object nor glass may be seen, yet the image shall seem to hang alone, pendulous in the middle of the chamber."

And walking about, you shall behold the image everywhere. But is such a thing fit to be discovered by the people? Shall I do such an unworthy act? Ah! my pen falls out of my hand. Yet my desire to help posterity, overcomes. For perhaps from this gleaning as it were, greater and more admirable inventions may be produced. Let it be so. Get a Sphaerical Cylinder, or Convex diffection of a Pyramidal Concave, the portion of which segment is not known. But let it be that which may descend upon his right angle by half cylinder and a square, and is parted by an oblique angle. Of two parts it must be received pendulous, and beneath in the half of its diameter it is conveyed from the middle. Let all the windows of the house be shut. Stop all the chinks, that the light may not come in beneath. In that place where the spectacle is prepared, if the sun or moonbeams fall in, the whole show is spoiled. So place the beams of the image that are beaten back, that the head of it may by repercussion fall right upon the earth. So will the visible object that comes by repercussion fall be reflected above and beneath. It will follow the fashion of the first glass. Let a brass or marble table be so placed upon it, as we said, and lest the light falling from the window should light upon the plain cylinder, and the crooked glass, it must be stopped by a shutter of a hands-breath, that is three times as broad as the hole. For it will break forth every way. You shall cover the apparition, that the image may be fitted very deep, that there may seem to be a pit. As the beams meet, let the spectator come, who cannot be in any great mistake. But cover your sight round, that the glass offend not your eye. Then is the image seen, and it shall not appear above the table, where the falling of the Cathetus will cut the line of sight through the center of the glass. I could open the matter no plainer. I have done what I could. I know that he who can understand it, will rejoice very much.

Chapter IX

"Mixtures of Glasses, and divers apparition of Images."

Now I will try to make a glass, wherein many diversities of images shall appear. And though such a one be hard to make, yet it will recompense all the diversity of images, and the benefit of it. If then you would...

"Make a Glass that shall represent much diversity of images."

Take a great or small circle, as you would have your glass, and here and there cut off two part of the circumference, one to the quantity of a Pentagon, the other of a Hexagon, as is clear in the Mathematicks. Let the arch of Pentagon be made hollow with some table, or Iron, that it may exactly receive it into it, and may seem to be cut out of it. But the side of the Hexagon shall be

contrary to this, for the quantity of that must be received by a Convex Table, that the arch of it may so stick forth. Then take a Foil of Wax or Lead, of a convenient thickness, that exceeds the breadth of the arch of the Hexagon, and in length exceeds them both. Then crook this plate so, that it may exactly stand in the hollow of the wood, that there be no space or chink left between them. Then let the Convex supersicies that is preserved prominent, be applied inwardly, according to the breadth of it, that the form of the concavity may not be against the Convexity, but that the same plate may receive both portions without the impediment. Having thus made your model, make your glass of steel, or of some other mixture, as I shall show you. And when it is polished, it will show you many diversities of images. First, the right parts will show right, and left, left. Whereas the nature of plain glasses, is to show the right side as left, and the left side as right. And if you go backwards, the image will seem proportionable, and will come forward. If you come more towards the Convex supersicies, the image will show ugly. And the nearer you come, the uglier will it show, and be more like a horses head. If you incline the glass, that will incline also. And by varying the glass, and the situation of it, you shall perceive diverse variations. Sometimes the head down, and the heels up, and you shall see many other things that I think not needful to relate now. For being placed on a voluble set, that it may show both parts before and behind, the spectator of himself may see all things. We may,

"Make a Glass out of all,"

That in that alone all images may be seen, that are seen in all. Many mouths, sometimes greater, sometimes less, sometimes right, sometimes left, some nearer, some farther off, some equidistant. If a crooked be set in one place, in another a Concave, and a plain one in the middle, you shall see great diversity of images. These are,

"The operations of Convex Cylindrical Glass."

When your face is against it, the more deformed it appears in length, the more ugly it is for slenderness. If the length of it cut the face overthwart, it shows a low pressed down face like a Frog, that you shall see nothing but the teeth. Almost the same way, as you shall see it in a sword, or any other long and polished Steel. If you incline it forward, the forehead will appear very great, the chin small and slender like a horses. But contrary to these are,

"The operations of Cylindrical Concave-glasses."

If you look into the Concave-glass, you shall see more images of the same thing, imitating the said glass. If you set your eye to the center, you shall see it all the breadth of the glass, so your forehead, mouth, and the rest. If you turn such a glass, that it may cut your face broadways, you shall presently see your head inverted, and the rest that I related in the Concave-glass.

"The operations of a Pyramidal Glass turned."

Are these. You shall see a sharp forehead, and a large chin. But the contrary way, a long forehead, with a very long nose. In a Concave you shall behold many faces, if according to the concavity you fit many portions of plain glasses. For one looking into it, shall find them as many as there are glasses, and all moving alike. and again, what glass soever it be, if it be not plain, it shall show always different from the image.

Chapter X

"Of the effects of a Lenticular Crystal."

Many are the operations of a Lenticular Crystal, and I think not fit to pass them over in silence. For they are Concaves and

Convexes. The same effects are in the Spectacles, which are most necessary for the use of mans life. Whereof no man yet has assigned the effects, nor yet the reasons of them. But of those more at large in our Opticks. That no space may be empty, I shall touch some things here, I call Lenticulars, portions of circles compacted together, of Concaves and Convexes. I will first show,

"How with a Convex Crystal Lenticular to kindle fire."

A Convex Lenticular kindles fire most violently, and sooner, and more forcibly than a Concave-glass. I give the reasons in Opticks. For being held against the sun, when the beams meet in the opposite part, it will kindle fire it is opposite to, melt Lead, and fire metals. Moreover, if you will,

"By night give light afar off with a Lenticular Crystal."

Set a candle a little behind the point of burning, so it will cast parallels a very great way to the opposite part, that you may see men pass the streets, and all things done in the chambers that are far from you. The same way as I said of a Concave-glass. We may,

"In a dark night, read a letter by a Lenticular Crystal."

Put the letter behind the glass, against the stars or candles a great way from you, where the beams meet, the words that are opposite will be clearly seen in a dark night, and the chamber shut. But that which follows, will afford you a principle far better for your consideration. Namely,

"By a Lenticular Crystal to see things that are far off, as if they were close by."

For setting your eye in the center of it behind the Lenticular, you are to look upon a thing afar off. And it will show so near that you will think you touch it with your hand. You shall see the cloths colors, men's faces, and know your friends a great way from you. It is the same,

"To read an Epistle a great way off with a Lenticular Crystal."

For if you set your eye in the same place, and the epistle be at a just distance, the letters will seem so great, that you may read them perfectly. But if you incline the Lenticular to behold the epistle obliquely, the letters will seem so great, that you may read them above twenty paces off. And if you know how to multiply Lenticulars, I fear not but for a hundred paces you may see the smallest letters, that from one to another the characters will be made greater. A weak sight must use Spectacles fit for it. He that can fit this well, has gained no small secret. We may,

"Do the same more perfectly with a Lenticular Crystal."

Concave Lenticulars will make one see most clearly things that are afar off. But Convexes, things near at hand. So you may use them as your sight requires. With a Concave Lenticular you shall see small things afar off very clearly. With a Convex Lenticular, things nearer to be greater, but more obscurely. If you know how to fit them both together, you shall see both things afar off, and things near hand, both greater and clearly. I have much helped some of my friends, who saw things afar off, weakly, and what was near, confusedly, that they might see all things clearly. If you will, you may,

"By a Convex Crystal Lenticular, see an image hanging in the Air."

If you put the thing to be seen behind the Lenticular, that it may pass through the center, and set your eyes in the opposite part, you shall see the image between the glass and your eyes, and if you set a paper against it, you shall see it clearly. So that a lighted candle will seem to burn upon the paper. But,

"By a Concave Lenticular to describe compendiously how long and broad things are."

A painter may do it with great commodity, and proportion. For by opposition to a Concave Lenticular, those things that are in a great plain are contracted into a small Compass by it. So that a painter that beholds it, may with little labor and skill, draw them all proportionally and exactly. But to leave nothing concerning Spectacles, I will show,

"How a thing may appear multiplied."

Among sports that are carried about, a Spectacle is of no small account. That glass instrument we put to our eyes to see the better with. For of those things that delude the sight, there can be no better way invented, then by the medium, for that being changed, all things are changed. Wherefore prepare that of very solid thick glass, that it may be the better worked by a wheel into proportions. Wherefore fit it into many forms and angles, whereby we desire to multiply anything. But in the middle of them, let the angles be pyramidal, and let it agree with the sight. That from diverse forms, images may be retracted to the eyes, that they cannot discern the truth. Being now made of diverse supersicies, set them to your eyes.   And if you look upon a man's face hard by, you will think you see Argus, one that is all eyes. If his nose, you shall see nothing but nose so his hands, fingers, arms, that you shall see no man, but Briareus the Poet, was said to have a hundred hands.

Chapter XI

"Of Spectacles whereby one may see very far, beyond imagination."

I will not omit a thing admirable and exceedingly useful. How blear-eye'd people may see very far, and beyond that one would believe. I spoke of Ptolomy's glass, or rather Spectacle, whereby for six hundred miles he saw the enemy ships coming. And I shall attempt to show how that might be done, that we may know our friends some miles off. And read the smallest letters at a great distance, which can hardly be seen. A thing needful for man's use, and grounded upon the Opticks. And this may be done very easily. But the matter is not so to be published too easily. Yet perspective will make it clear. Let the strongest sight be in the center of the glass, where it shall be made, and all the sunbeams are most powerful dispersed, and unite not, but in the center of before mentioned glass. In the middle of it, where diameters cross one the other, there is the concourse of them all. Thus is a Concave pillar glass made with sides equidistant. But let it be fitted by those sections to the side with one oblique angle. But obtuse angled triangles, or angled triangles must be cut here and there with cross lines, drawn from the center, and so will the spectacle be made that is profitable for the use I speak of.

Chapter XII

"How we may see in a Chamber things that are not."

I thought this an artifice not to be despised. For we may in any chamber, if a man look in, see those things which were never there. And there is no man so witty that will think he is mistaken. Wherefore to describe the matter, let there be a chamber wherein no other light comes, unless by the door or window where the spectator looks in. Let the whole window or part of it

be of glass, as we use to do to kee out the cold. But let one part be polished, that there may be a Looking-glass on both sides, whence the spectator must look in. For the rest do nothing. Let pictures be set over against this window, marble statues, and suchlike. For what is without will seem to be within, and what is behind the spectators back, he will think to be in the middle of the house, as far from the glass inward, as they stand from it outwardly, and so clearly and certainly, that he will think he sees nothing but truth. But lest the skill should be known, let the part be made so where the ornament is, that the spectator may not see it, as above his head, that a pavement may come between above his head. And if an ingenious man do this, it is impossible that he should suppose that he is deceived.

Chapter XIII

"Of the operations of a Crystal Pillar."

Nor shall the operations of a Crystal Pillar go unspoken of, for in it there are some speculations not to be despised. First,

"To kindle fire with a Crystal Pillar ,"

By opposing it to the sun, it will kindle fire behind it about the circumference. Often left above the chamber, when the sun shined, ti burned the blankets. They that will, at set hours and places, burn enemy camps, if it be laid upon fuel for fire, ti will certainly kindle it. We may also,

"With a Crystal Pillar, make an image hang in the air."

It will show the image hanging in the air, both before and behind. Let the object be behind the pillar, let the pillar be between that and the eye, the image will appear outwardly hanging in the air, above the pillar, parted everywhere from the pillar, clearly and perspicuously. And if the visible object be between the eye and the pillar, the image will appear behind the pillar as I said. If it be a very visible object, as fire or a candle, the matter is seen more clearly without any difficulty. I gave the reasons in my Opticks. We may also,

"In a Crystal Pillar see many Rainbows."

Make a solid pillar in a glass furnace, so great as a Walnut, and let it be made round only by the fire, as the manner is, as glass makers used to do. That without any help of the wheel, the outward supersicies may be most polite. Where the Iron touched it, there leave a pedestal. It is no matter for pure glass, for impure is best. Place this upon your eye, and a burning candle against it. The light refracted by the bladders will show infinite Rainbows, and all the light will seem golden colored, that nothing can be more pleasant to behold.

Chapter XIV

"Of Burning Glasses."

I proceed to Burning Glasses, which being opposed against the sunbeams, will kindle fire upon matter laid under them. In these also are the greatest secrets of nature known. I shall describe what is found out by Euclide, Ptolomy, and Archimedes. And I shall add our own inventions, that the readers may jude how far new inventions exceed the old. Fire is kindled by reflection, refraction, and by a simple compound glass. I shall begin from a simple reflection, and from,

"A Concave-glass that shall kindle fire behind it."

Which few have observed. Know, that a Concave-glass will burn from its middle point, unto the hexagonal side above the glass, as far as a fourth part of its diameter. From the hexagonal side, as far as the tetragonal without the glass, on the lower part of it. Wherefore cut off that part of the semicircle, which is situated from a Pentagon as far as a Tetragon, as it were the band of the circle. And this being polished, and opposed against the sun, will cast fire far from it, behind it. I will say no more, because I said more at large in my Opticks concerning this. So also we may,

"With a Concave Crystal Pillar or Pyramidal, kindle fire."

But very slowly, with delay only, and in the summer sun. It kindles in the whole line, and not in a point, but bing extended by the point of ascension of its circle. The same will fall out by a Pyramidal Concave.

Chapter XV

"Of a Parabolical Section, that is of all glasses the most burning."

That is called a Parabolical Section, that more forcibly farther off and in shorter time, will set matter on fire. That is opposite to it. It will melt Lead and Tin. My friends related to me, that Gold and Silver also. But I have made them red hot. By which invention of Archimedes, as appears by the testimony of Galen, and many more. We read that he set the Roman Navy on fire, when Marcellus besieged Syracuse, his Country. Plutarch, in the life of Pompilius, says, the fire that burned in Diana's Temple, was lighted by this glass. That is, by instruments that are made of the side of a right triangle, whose sides are equal. These made hollow, do from the circumference respect one center. When therefore they are held against the sun, so that the beams kindled may be gathered from all parts, and be united in the center, and that they do fever the air rarefied. It soon sets on fire all fuel that is combustible opposed against it, by kindling first the lightest and driest parts. The beams being as so many fiery darts falling upon the object. In a Concave Spherical Glass, the beams meeting together, kindle fire in a fourth part of the diameter under the center, which are directed within the side of a Hexagon from the supersicies of the circle. But a Parabolical Section, is, wherein all the beams meet in one point form all parts of it supersicies. Cardanus teaches how such a glass should be made. If we would kindle fire at a mile distance, we must describe a circle, whose diameter must be two miles long. And of this we must take such a part, that the roundness of it may not lie hidden. Namely, a sixtieth part, to which we must add a Dimetient, according to the altitude in one point, and upon the fixed diameter must we bring about part of the circle, which shall describe the portion of a sphere. Which we have polished. If we hold it against the sun, it will kindle a most violent fire a mile off. It is strange how many follies he betrays himself guilty of in these words. First, he promises a glass should burn a mile off, which I think is impossible to burn thirty feet off. For it would be of a wonderful vastness, or the supersicies of the Cane is so plain and to receive any crookedness, it can hardly be made so great. Moreover, to describe a circle, whose diameter should be two miles long, what Compass must we use? And what plate shall we make it on, or who shall draw it about? And if it be true, that Archimedes by a Parabolical Glass did burn ships from the wall, the distance could not be above ten paces, as appears by the words of the authors themselves. For in the same place he raized the ships, and threw them against the rocks. And his engines were Iron bars, the greatest part whereof lay backward. And by reason of those Iron Crows, it is manifest it could be done in no other ways. There are other fooleries, but I pass them for brevity sake, that I might not seem tedious. The

cause of his error was, that he never had made any such glasses. For had he tried it, he would have spoken otherwise. But I will now show how,

"To make a Glass out of Parabolical Section."

The way to describe it is this. Let the distance be known how far we would have the glass to burn, namely, A B ten foot. For if it were more, it could hardly be done. Double the line A B, and make A B C, the whole line will be A C. From the point A, draw a right line D A, and let D A and A E be equal one to the other, and cut at right angles by A C. But both of them must be joined to the quantity A C, as D C E, which in C make a right angle, D C E. Therefore the triangle D C E is a right angled triangle, and equal sides. And were this turned about the axis C D until it come to its own place whence parted, there would be make a right angled Cane, E D N C, whose Parabolical Section will be A B C. The right line D C will be the axis of the Cane, and C E shall be the semidiameter of the basis of the Cane. Through the point C you must draw a line parallel to D E, and that is H I of the length of C E and C D. And by the point B draw another parallel to the said line E D, which is F B G. And let B G and B F be both of them equal to A C. So F G shall be the upright side, and H I the basis of the Parabolical Section. If therefore a line be drawn through the points H E A G I, that shall be a Parabolical Section, the diagram whereof is this that follows. But if you will burn anything, you must not make your Parabolical Glass to the bigness of the whole line H F A G I, but only take a part thereof, as if we would take the top part of it L A M, that the line L M may cut A C in K, or greater or lesser. If you will make one greater, cut off A K beneath it. For the bigger it is, the more quickly and vehemently will it burn. If you will have it less, take it above A K. But thus you must do, that the crooked line L A M may be more exactly described, that you may not commit the least error. Wherefore on a plain table I protract the line A B C, and let A B be double the distance, that we intend to burn anything, that is, the length of the line A B C. From the point B, I raise a perpendicular line B D, the altitude whereof must be of the same semidiameter of the section to be made, that is the line L M, the half whereof is L K. From thence describe a semicircle, whose beginning A must pass through the point D. But you shall find the center thus. Let the points A D be joined by a line, and let the angle B A D be made equal to A D E, and the line D E drawn forth, shall cut A C in F, that shall be the center. So draw the semicircle A D C. If therefore we shall cut the line B C into smaller parts, so much the lesser parabolical line must be described. Divide it into four parts, and let the points of the divisions be H G F. Then describe three circles, that shall be determined by A from the three points H G F. The first is A F, the second A G, the third A H. And they shall cut the line B D. The first in F, the second in G, the third in H. Thence I take my section to be perfected L K M, and I cut the line K A into four parts, and through those points I draw parallel lines to L M. Let B H be the nearest to the top of the Parabolical Section, the second B G that follows next, and the third B F next to that, and after shall be L M. Then by the lines L F G H A, draw a crooked line, and do the same on the other part so far as M, and that shall be the line sought for, so make the Parabolical Section, and from that must be made the glass, as I shall show.

Chapter XVI

"How a Parabolical Section may be described, that may burn obliquely, and at a very great distance."

I have described a Parabolical Section, which might be made by the rule and Compass, because we may use it at a short distance. But in greater distance we must proceed by numbers. As for forty or for sixty foot. And not much more lest the glass should be made of unusual magnitude. The foresaid glass burns between it and the sun. And if the sun be not as you desire it, the operation is lost. So also by an oblique glass, that is between the sun and the combustible matter, or over against it. Whence according to the situation you may use them all, namely, wherein they answer your expectation. And especially when the sun is in the meridian, they burn with more vehemency. This I must tell you, that you may not be deceived. For when you error, you commonly draw others into error with you. A Parabolical Glass made from the top, if the section shall be from

the top, if we would burn far, the glass will be plain. And that it may have some crookedness, it will be wonderful great. And if the section be about the basis, that will be worst of all. For from the least distance, it will be almost flat. Wherefore that we may have it with some crookedness, we must take a line about the neck of the section, not the head, nor the feet. Wherefore being to make a glass of a Parabolical Section, about the neck of the section, where the greatest crookedness of the Parabolical Section is made, and that may burn from its supersicies, to twenty foot distance. Let the line A B be the Finus Versus eighteen foot long. From the point A, I raise a line to right angles with A B, which shall be the line by which, the fourth part whereof is A B. Cut A B in C, and let it be two foot, and C B sixteen foot. I multiply twice seventy two, and that makes one hundred forty and four. The square root of this is twelve. Wherefore the line erected perpendicularly from the point C, unto the circumference of the Parabolical Section, will be D I of twelve foot, wherefore C I will be the line appointed. Join I B, and the radius that must burn, will be in the point B that was sought for. Wherefore the ray of the sun, that is equidistant to the Finus Versus H I, is reflected by I B in B. The Latitude whereof will be about twenty foot. For the line I C of twelve foot, multiplied into itself, makes two hundred fifty and six. Add these together, and they make four hundred. The square root of it is twenty four, thus. Wherefore I am resolved to take the part of the glass, intercepted between the points I and F, and I seek twothirds of one foot, from C toward B, and I divide one foot into thirty parts, and the crookedness may be taken more precisely. And let C G be twenty parts of a foot, from A to C sixty parts, because they are two foot. Wherefore from A to G, where we shall make our glass, will be eighty parts. Wherefore let us begin from A C sixty parts, to which I always add four Cyfers 0000. For this purpose, that when numbers come forth, whose roots cannot be extracted, those that are taken may be the least loss. Wherefore we shall make the table under written. In the first line are the points of the Finus Versus, namely, the length A E, is seventy two foot. If we shall reduce these to parts, by multiplying by thirty, there comes forth 2160. Multiply by the parts of the Finus Versus A C, there will arise 129600. In the third line are roots of the foresaid number, namely, the line appointed. Adding therefore to 129600, four Cyfers , one signifies the tenth part of a foot, another the tenth of a tenth part. Thus, 360.0.0.0.0. So will be the foresaid table made.

These things being done, I take the differences of the roots, of the greatest to the smallest, for they are from 160.0.0. to 415.6.9. Make choice of the measure of a foot, according to which distances we would make our glass. Let it be A B, which we divide into thirty parts. And take twenty parts, namely, namely, twothirds. I add a line to it at right angles, namely B, and let it be B C, which I divide into fifty five parts. I divide one part into ten, and that one into ten parts more, and those are tens of tens. Let A be Nul, that is a Cyfer, and there place sixty. The second part sixty one. The line joined to right angles, will be two. The third part sixtytwo. The line joined to it will be five. So the twentieth part will be eighty, and the line joined to the angle fiftysix. To the extremities of these lines I fasten a pin, and I put a brass Cithern-wire upon them, and upon it I draw a line, and the parabolical line is exactly described by it. For should we draw it without the help of this cord, it will be wavering, and not perfect. Then take a brass table of convenient thickness, and draw the line now found upon it, filing away all that shall be above the line C A. These things being done, take an iron rod of an exact length, namely, twelve foot, as the line D C, and at the end fasten a plate which shall be for the circumvolution of the axis. At the other end fasten a spike, that it may be fastened somewhere, and handsomely turned about. So being will fixed, we turn it about, by adding clay mingled with straw, that it may excellent well make a hollow place, like to the form of a Parabolical Section. Which being dried, we must make another solid one, that it may contain the liquid metal, as the manner is.

Chapter XVII

"A Parabolical Section that may burn to infinite distance."

Zonaras the Greek, writes in the third Tome of histories, that Anastasius moved sedition against Vitalianus a Thracian, and he got those of Mysia, and the Scythians to stand with him. And in the country of Constantinople, he plundered the people, and

besieged the city with a fleet. Marianus the deputy opposed him. And there being a fight at sea, by an engine made by Proclus a most excellent man, for he then was famous for his philosophy and Mathematicks. For he not only knew all the secrets of the most eminent artificer, Archimedes, but he found out some new inventions himself. The enemy navy was vanquished. For Proclus is reported to have made burning glasses of Brass, and to have hung them on the wall against the enemy ships. And when the sunbeams fell upon them, that the fire broke forth of them like to lightning. And so burned their ships and men at sea, as Dion reports that Archimedes did formerly to the Romans besieging Syracuse. But I will show you a far more excellent way than the rest, and that no man as ever I know wrote of. And it exceeds the invention of all the ancients, and of our age also. And I think the wit of man cannot go beyond it. This glass does not burn for ten, twenty, a hundred, or a thousand paces, or to set distance, but at infinite distance. Nor does it kindle in the Cane where the rays meet, but the burning line proceeds from the center of the glass of any Longitude, and it burns all it meets with in the way. Moreover it burns behind, before, and of all sides. Yet I think it an unworthy act to divulge it to the ignorant common people. Yet let it go into the light, that the immense goodness of our great God may be praised and adored. Because a proportional radius does proceed from the greater section, from the less is made the greater. To avoid this, make it of a Cylindrical Section, for it is the mean, and let it be set for the axis of the small and of the greater deflection, which may pass through the middle parallels. This held against the sun, does make refraction of the beams sent into it, very far, and perpendicularly from the center of a Cylindrical Section. And in this art the reason cannot be found, that the beams uniting should part again. Wherefore it receives them directly, which it sends back again obliquely into beams far from the supersicies of it. For the beams passing through the narrow hole of a window, are forthwith dilated. Nor is their proportion kept, by being far removed, therefore it may reverberate and burn where the Cane seems clearest, which will be near the center. Nor is it far distant from that point, from the supersicies of the glass, called Parabolical, which must remain firm in that place which I said before. Let experiment be made of its virtue, by threads passing from its center, or Iron wire, or hair. And it is no matter whether it be Parabolical or Sphaerical, or any section of the same order. Then let it be excellent well fitted upon the center of the said section. If the rays go forth above, or a little beneath, it is no matter, if not much money, or much money be laid out to make it. The making of it depends merely on the artificers hand. The quantity is nothing, be it small or great. The Latitude of the hollow is not necessary. Only let it be sent forth from the middle, that the rays may meet excellent well in the center. Let the window be made open aflaunt, that it may receive a Parabolical Glass. And thus shall you have a glass, if that be well done I spoke of. "He that hath ears to hear, let him hear." I have not spoken barbarously, nor could I speak more briefly, or more plainly. But if a small one does not answer a great one in proportion, know that you will operate nothing. Let it be large about the basis, small at the top, equidistant to the first. Let it not be a Steel glass, because it cannot sustain the heat of burning, and by burning it loses its brightness. Let it be therefore of glass a finger thick. Let the Tin Foil be of purged Antimony and Lead, such as they make in Germany. Let the form be of clay. Put the glass upon it, and melt it in a glass furnace, that it may take its form. This is a wonder, that that which causes so much burning in work, is cold, or at most but lukewarm. If you would have it burn before, of the section which is about the basis, make a circle, in the middle point whereof fit the artifice, that the ray returning, may come forth to the fore part. This I have said. And I have observed, that we may use this artifice in great and wonderful things, and chiefly by inscribing letters in a full Moon. For whatsoever we have written by this glass, as I said of a plain glass, we may send letters of it to a very great distance. And because I said it sends forth to infinite distance, it is sent as far as the Moon, especially being helped by its light.

Chapter XVIII

"To make a Burning Glass of many Sphaeral Sections."

Vitellio describes a certain composition of a burning-glass, made of diverse Sphaeral Sections. But what he writes he proves not, nor does he understand what he says. While I was searching for that, I found this. Propound the distance of combustion, let it be C B, let it be doubled, C A shall be the semidiameter of the sphere whose center B must be extended to D, and the diameter will be A D. Divide C A into four points. But the more the parts are, the more precise will be the description of the

line, and set the numbers to the divisions. So setting the foot of the Compass fast in I, and the movable foot in B, make the semicircle E F, and mark it B I. And setting it in the center at the same wideness, and the other movable foot in the line B D, describe another semicircle and mark it 3. And so to the fourth and mark it 4. Then setting the foot firm in B, at the distance of B C, or B4. Make a circle, and the immovable foot standing on the center B, upon the distance B3, describe another. So there is the third B, and the fourth B A, as B I. Then from the point, A, draw a line, and another from the point B. And let them meet in a point where the circle meets with the semicircle. For let them be cut in G. Then draw the second line from circle 2. And another from the same A the center. And let them meet where the second circle cuts with the second semicircle in H. Then from the third circle, and from the B the center, and where they meet in, I, by the meeting of the semicircle. So from the fourth, where the fourth begins in K. And from K I H G draw a line, which shall be the section to be described. The same may be done on the other part of the circle. The reason is this. The beam of the sun L falling upon the point l, of the glass, is reflected to B, because B 3 and B I are equal from the same circle. Therefore the angle B 3 I, is equal to B I 3. But B 3 l is equal to 3 I L, because it is subalternate, for the ray of the sun L I is equidistant to the diameter of the circle, wherefore the angles L I 3 and 3 I B, are equal, therefore it is reflected upon B. The same is to be said of the beam M H and N G, and this glass is contrary to a Sphaerical Glass. From diverse points of the circumference, the rays are reflected upon different parts of the diameter, and all the diameters are from the center. But in this the reflected beams unite, not in one point, and the diameter are various from the fourth of the diameter. But of this more largely in my Opticks. Lastly, I will not omit that the Cane does kindle fire circularly, when that as far as this circle it kindles in a point. Divide the parabolical line by Finus Versus, and let them meet upon contrary parts. For example, let the Parabolical Section be C E F, the fInus Versus D E. Cut this circumference in E, and let C F meet together in the manner they stood before, that it may be E G F E. And about the axis G H tun it round. There will be made a round Cane . Make it of Steel, or other metal, and polish it, and it will kindle fire round about.

Chapter XIX

"Fire is kindled more forcible by refraction."

I have spoken of burning-glasses by reflection. Now I shall speak of those which burn by refraction. For these kindle fire more violently. I shall show my reason in the Opticks. Wherefore,

"By a Cylinder of Crystal to kindle fire."

We may do it by setting it against the sun. But very slowly and by leisure. For all the beams do not meet in one point, but in a line. The same way almost are we want,

"To burn with a Pyramidal Crystal Glass."

But this burns about a line, yet both burn more strongly than a pillar glass of a pyramidal, in the place of this we may use a vial full of water. But the most violent of them all, is with,

"A Crystal Sphere, or portion of it."

And if a sphere be wanting, we may supply it with a vial full of water, that is round and of glass, set against the sun. If you set behind it any combustible matter, that is friendly to the fire, so soon as the rays unite about the supersicies, it forthwith kindles fire to the wonder of the spectators. When they see fire raised from the water, that is extreme cold, so will the portions of spheres, as Spectacles, Lenticulars, and such like, which we spoke of already.

"A Crystal Parabolic-glass will kindle fire most vehemently of all."

We shall see it, because the beams all meeting, it kindles more than a glass. We may also, as I said of a glass,

"By refraction, kindle fire afar off."

And almost to infinite distance, as is demonstrated by opick reasons. And the more by how much as refractions work more forcibly than reflections. And I shall perform this many ways, as I said before, not only by reason, but by experience. Almeon said, that he made the same way parallel lines cut a cross. I have said also, that if they be opposed in place, Crystal spheres are so perfectly opposite by coition, as are sphaeral and cylindrical portions. Nor do they cast forth fire so far, that if is hard to believe it, and more than imagination can comprehend. Behold, I shall show you a more forcible way to kindle fire. It sends forth also unequal, and combust parallels. Let a uniform section fall in, and it will carry forth oblique beams, you shall see the fire by a hidden and open beam, falling upon a right supersicies, and it will come forcibly and uniformly into that place, where the beams unite most in a fit combustible matter. For if that combustible matter that is opposite, be not dry, it is in vain to set a glass against it, either a Convex Cylindrical, or Concave Sphaerical. For the matter will be found almost pierced through with strong fire. And if it be not truly opposite it will burn, whether it be small or great. But it is considerable, the portion of which it is. It will do also the same thing, if the thing be opposite, and be small or great, if need be.

Chapter XX

"In a hollowed Glass how the image may hang without."

Before I depart from a plain glass, it is performed by the later artist's industry, that in the same glass many faces may be seen, or likenesses of the same image without any hindrance to the first. For behind it they make the glass hollow, and make a little Concave, whence a Foil being laid on, as I shall show. And fitted well, it will hold another forth without. Hence comes it to pass by this excellent invention, that a man looking in a glass, may see the upright image of some other thing. And wondering at it, catching at it, he can catch nothing but air. I remember that I have often seen it, and the matter is thus. A glass being made of Crystal, they make a hollow place on the backside like an image, as curiously as they can. Then they Foil it over, and set it in its place, now as deep as the hollow is within, so much will it show itself without the supersicies. And you cannot satisfy yourself, unless you touch it with your hands, whether it truly stick without the glass or not. So letters are truly read, that they will seem to be made in Silver upon the Crystal. Nor is the eye so quick, but it may be deceived when it looks on. Nor will I omit the artifice,

"To see in a plain glass that which appears nowhere."

I have often much delighted my friends, and made them admire with this glass. Provide thirty or forty littles ready, of a foot and half long, and two fingers broad, and a third part of a finger thick. So artfully hewn, that the thickness may be upon the one side, and the thinness on the other side, like the edge of a knife. Place all these boards together, that the solid parts may stand altogether, as to make a perfect plain. Then paint your own picture, or of some other thing upon it. Yet by this artifice and great observation, that if the image be near the glass, it must be drawn as it were afar off. If you would have it far distant, let the forehead be unmeasurably long, the nose somewhat longer, and the mouth, and the chin, likewise. The manner how to draw this form exactly in tables, I said in my Opticks. When the image is now described, fasten the little boards upon a plain table. That the head may be set downwards, and the chin upwards. And place the first table after the second, and the second after the third, till they all be fastened. Hang the table above a man's height, that no man may see into it, above the degrees of

the tables. And place a glass over this, distant two foot from the table, so long lifting it up, and putting it down till you see the perfect image. Now when any man comes near the glass to see his own image, he shall see the image of some other thing that appears nowhere. In the breadth of the tables you may draw some picture, lest they should give some occasion to suspect.

Chapter XXI

"How Spectacles are made."

We see that Spectacles were very necessary for the operations already spoken of. Or else Lenticular Crystals, and without these no wonders can be done. It remains now to teach you how Spectacles and Looking-glasses are made, that every man may provide them for his use. In Germany there are made glass balls, whose diameter is a foot long, or thereabouts. The ball is marked with the Emril-stone round, and is so cut into many small circles. They are brought to venice. Here with a handle of wood are they glued on, by Colophonia melted. And if you will make Convex Spectacles, you must have a hollow iron dish, that is a portion of a great sphere. As you will have your Spectacles more or less Convex, and the dish must be perfectly polished. But if we seek for Concave Spectacles, let there be an Iron ball, like to those we shoot with Gunpowder from the great Brass cannon. The supersicies whereof is two, or three foot about. Upon the dish, or ball there is strewn white sand, that comes from Vincentia, commonly called Saldame, and with water it is forcibly rubbed between our hands. And that so long until the supersicies of that circle shall receive the from of the dish. Namely, a Convex supersicies of it exactly. When that is done, head the handle at a soft fire, and take off the Spectacle from it and join the other side of it to the frame handle with Colophonia, and work as you did before, that on both sides it may receive a Concave or Convex superficies. Then rubbing it over again with powder of Tripolis, that it may be exactly polished. When it is perfectly polished, you shall make it perspicuous thus. They fasten a woolen cloth upon wood. And upon this they sprinkle water of Depart and powder of Tripolis. And by rubbing it diligently, you shall see it take a perfect glass. Thus are your great Lenticulars, and Spectacles made at Venice.

Chapter XXII

"How upon plain Concave and Convex Glasses, the foils are laid on and they are banded."

Now it remains that I speak of some few things, not to be overpassed of the banding of Convex-glasses. And of foiling plain glasses and Convex-glasses, that so I mat set down the perfect science of Looking-glasses. First, for the terminating of Looking-glasses, that are made of Crystal and Glass, then of other mixtures, and polishings, that a knowing artificer may know, and know how to make them. For though among many things, that show the images of things, as water, some jewels, and polished metal do it. Yet nothing does so plainly represent images, as Lead foiled upon Glass. Plain Looking-glasses are prepared of Crystal, and of Glass. Those of Crystal are polished by wheels, and require another artifice. But at Venice,

"How Glass Looking-glasses are made,"

I have seen it. They take the melted glass out with an Iron. With their Blast they frame an empty Pillar. They open it on one side with their Tongs, and while it is red hot they lay it upon a plain plate of Iron, that is equally made. And they put it into the furnace again, to make it softer and that it may get the perfect plainness of their Iron plate. They leave it over the furnace to

cool by degrees. When it is cool, they do thus,

"Polish plain Glasses."

They fasten it upon a plain table with Gyp. Underneath lies a most polite plain plate of Iron. They cast upon it the foresaid sand. They rub it with water by a stick, leaning thereon, until it be perfectly plain. They take it from the table, and glue it on the other side, to polish them both. Then they make them perspicuous, as I said they did. Now I will show,

"To terminate plain Glass Looking-glasses"

Glass or Crystal Looking Glasses, when they are made plain and equal, the artist makes a Foil of the same bigness of Tin, that is level and thin, as perfectly as he can. For if Crystal or Glass had no Foil of Lead behind it, by its strength and thickness it could never terminate our sight, nor stay the image printed on it, but it would let it slip away. For Glass is pure and transparent, and so would not contain it, by reason of its brightness. And so the image would vanish with it, as light in the sun. Wherefore upon this Foil you shall wipe over with Quicksilver, by the means of a Hare's foot, that it may appear all as Silver. And when you see it fast on the supersicies, you shall put it upon a fair white paper, and so upon the Glass. But first made clean with a linen clout, and polished. For if you handle it with your hands, the Foil will not stick to it. With your left hand press down the glass, and with the right take away the paper, that the foil may cleave everywhere and they bind fast together. Laying a weight upon it for some hours, and so let it stand and stir not. Now I will show,

"How a Foil is put upon a Concave Glass."

But it is more laborious to lay a Foil on a Concave Glass. Prepare then a Foil of the bigness of your glass, that you shall lay upon the Convex supersicies. And holding it fast with a finger of your left hand upon the center, with your right hand you shall fit the Foil around about, and shall extend it on the said supersicies, until it becomes of the same form with that Convex supersicies, and stick everywhere even unto it. Then of moist Gyp shall you prepare a form of the glass, namely, by pouring Gyp upon the Convex supersicies. And when the Gyp is dry, you have the form. Upon the form extend a Foil of Tin, and let it agree perfectly with the form everywhere, because the form and the Foil are made after the same supersicies. Strew Quicksilver upon the Foil, and as I said, make it stick by means of a Hare's foot. The artists call this Avivare. Put paper upon it, and pressing this upon the glass, take away the paper. When you know it sticks fast, take away your hand, and lay on a weight, and after take it away, but with a careful balancing of your hand, lest it take wind, and that the Quicksilver may all stick fast everywhere. Now remains how,

"To terminate Convex-Glasses."

Make Glass balls, but of pure glass, and without Bladders as much as you can, as the receivers for distillations. And from the hollow Iron that it is blown in by, let this liquid moisture be projected, namely, of Antimony and Lead. But he Antimony must be melted twice or thrice, and purged, and cast Colophonia in. So stir the mixture in the hollow vessel, and what remains cast forth. And so in Germany they make Convex-Glasses.

Chapter XXIII

"How metal Looking-Glasses are made."

But metal glasses are made another way. Wherefore if a Parabolical-Glass be to be made, draw a parabolical line upon a

Brass or wooden table. What is without it must be filed away, and it may be equal, smooth, and polished. Fasten it upon an axis in the middle, and fit it with instruments, that may be fitly turned about. Let there be clay with straw under it, made up with Dung, that the table being turned about, it may receive a Concave form exactly. Then let it dry, strew ashes upon it, and plaster clay above that, of a convenient thickness. Let it dry by the fire, or if you will , by the heat of the sun. Take it off. For it will easily part from the ashes. Unite them together, that as much space may be between both forms, as you think fit, for the thickness of the glass. When it is dry, cover it with this, leaving an open orifice on the top, and some breathing places, that the air may breath forth at it. Then make such a mixture. Let them be put into a new pot that will endure the fire, and lute it well within, that it may hold the faster. Let it dry well, and do this twice or thrice over. Set it to the fire, and melt in it two pounds of Tartar, and as many of White Arsenic. when you see them fume, pour in fifty pounds of old Brass, often used, and let it melt six or sever times, that it may be pure and cleansed. Then add twentyfive pounds of English Pewter, and let them melt together. Draw forth some little of the mixture with some Iron, and try it, whether it be brittle or hard. If it be brittle, put in more Brass. If too hard, put in Pewter. Or else let it boil, that some part of the Pewter may evaporate. When it is come to temper it should be, cast upon it two ounces of Borax, and let it alone till it dissolve into smoke. Then cast it into your mold, and let it cool. When it is cool, rub it with a Pumice-stone, then with powder of Emril. When you see that the supersicies is perfectly polished and equal, rub it over with Tripolis. Lastly, make it bright and shining with burnt Tin. Most add a third part of Pewter to the Brass, that the mass may be the harder, and become more perspicuous.